”COHERENT+ decay-at-rest coherent ν"

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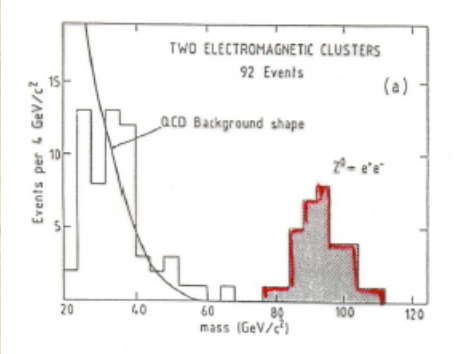
WINP Feb 5, 2015

Standard Model

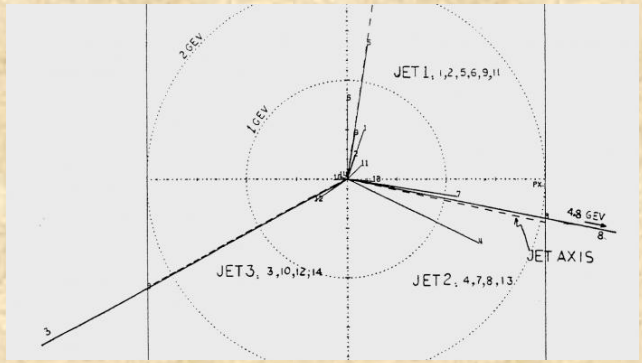
Formulated ~ 50 years ago, become driving force for HEP ever since

Short list of highlights (predictions and discoveries):

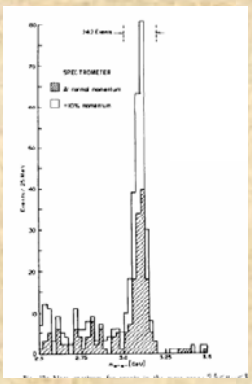
W and Z bosons



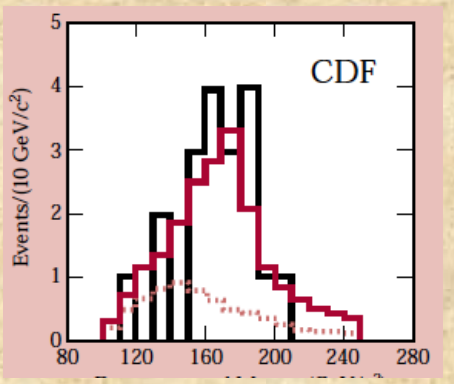
Gluons



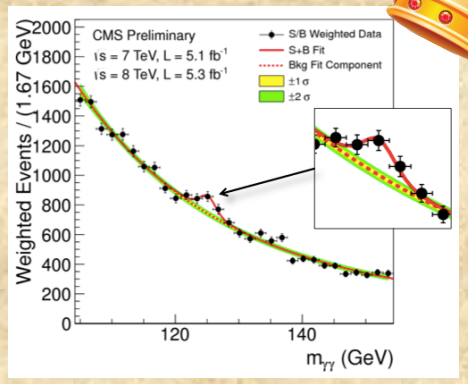
Charm Quark



Top Quark



Higgs boson

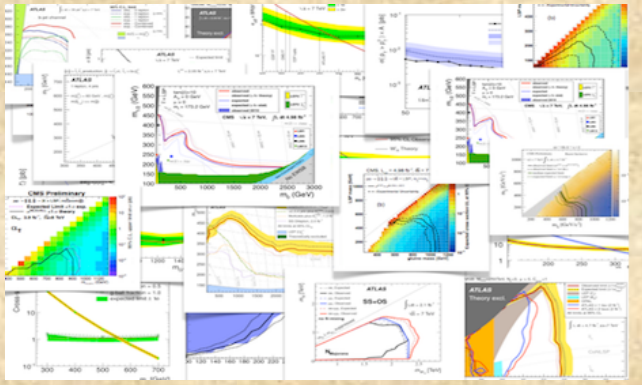


Search for extension of the SM

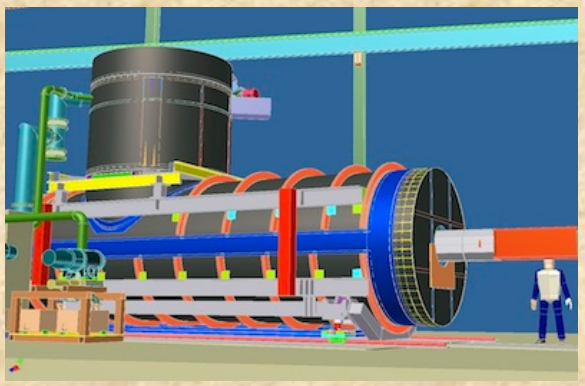
It is motivated by unexplained phenomena like Dark Mater and Dark Energy, Gravity, Neutrino masses, matter-antimatter asymmetry

Some big price tag examples

Search for SUSY at LHC

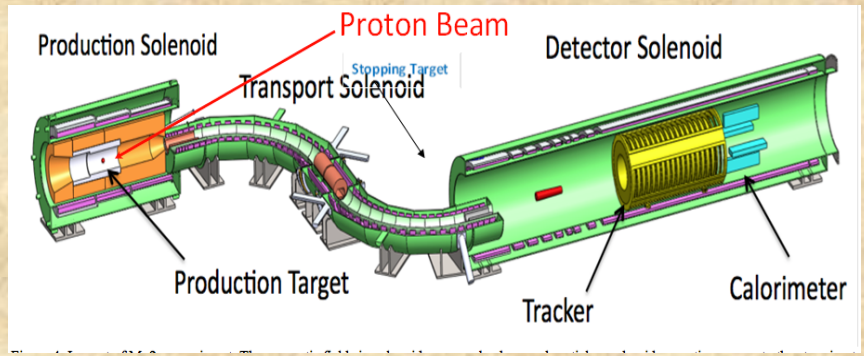


Search for Neutron EDM



g-2

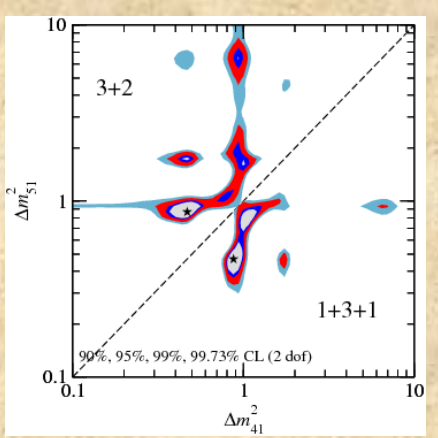
mu2e



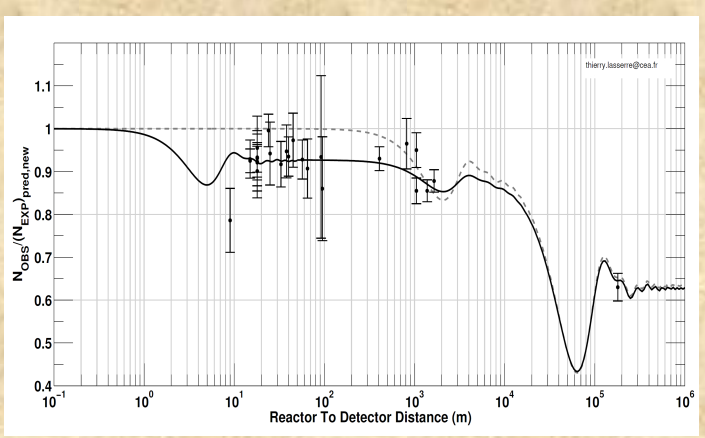
Do we have smoking guns in neutrino sector?

Non zero neutrino mass and large amplitude mixing are well established facts

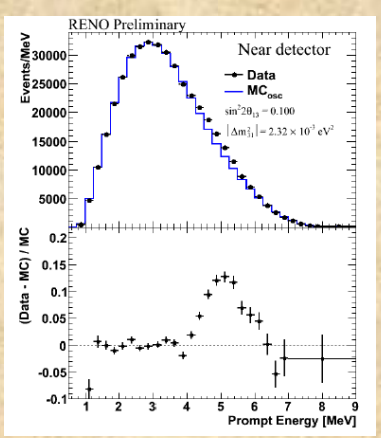
Sterile Neutrinos



Reactor Anomaly



Bump in reactor spectra



There is a world wide effort to confirm or rule them out

Are we extensively checking neutrino sector to look for the vSM?

Neutrino Neutral Current Coherent Scattering

$$\frac{d\sigma}{dT_A} = \frac{G_F^2}{4\pi} m_A \left[Z\left(1 - 4\sin^2\theta_W\right) - N \right]^2 \left[1 - m_A \frac{T_A}{2E_\nu^2} \right] F^2(Q^2)$$

$$\sigma_{tot} = \frac{G_F^2 E_\nu^2}{4\pi} \left[Z\left(1 - 4\sin^2\theta_W\right) - N \right]^2 F^2(Q^2)$$

m_A – *nucleus mass*

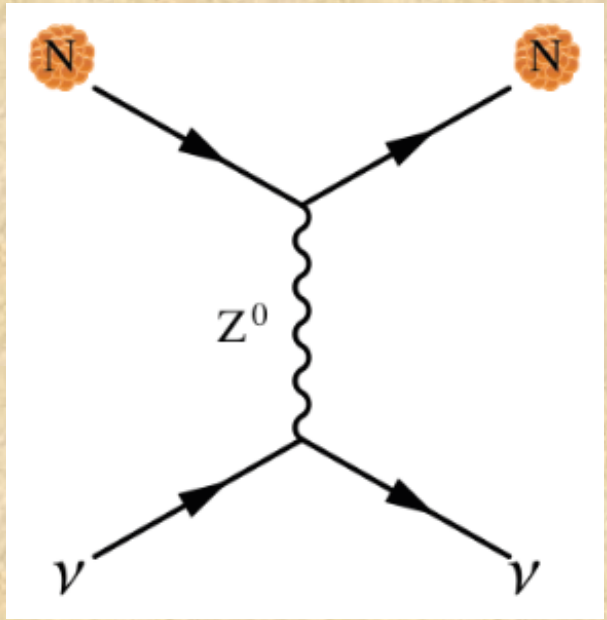
T_A – *kinetic energy of recoil nucleus*

E_ν – *neutrino energy*

Z – *nucleus charge*

N – *number of neutrons in the nucleus*

F *is nucleus form factor*



D.Z. Freedman PRD 9 (1974)

A. Drukier & L. Stodolsky, PRD 30, 2295 (1984)

Horowitz et al. astro-ph/0302071

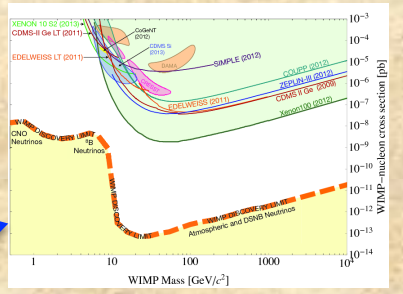
$$E_\nu < 50 MeV$$

This process has well predicted cross section.

It never been detected.

It is playing important role in core collapse SN dynamics

Could become irreducible background for DM experiments



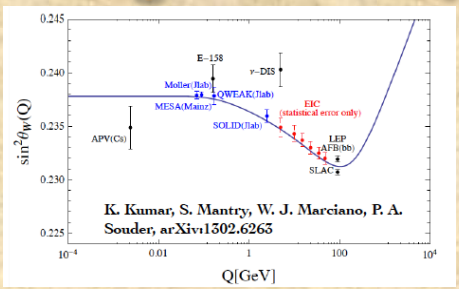
If we detect it and see agreement with the SM

Next after the "first light"→ experiments with multiple targets

Tool for precise measurement of electro-week angle at low Q^2

$$\sigma_{tot} \approx \left[Z\left(1 - 4\sin^2\theta_W\right) - N \right]^2$$

Require a few different targets



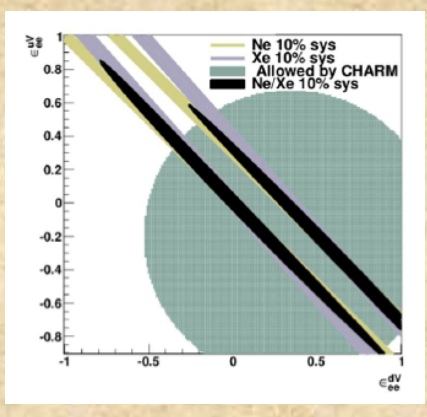
Search for nonstandard interactions

K.Scholberg arXiv 0511-042

$$\frac{d\sigma}{dT}_{coh} = \frac{G_f^2 M}{2\pi}((G_V + G_A)^2 + (G_V - G_A)^2(1 - \frac{T}{E_\nu})^2 - (G_V^2 - G_A^2)\frac{MT}{E_\nu^2})$$

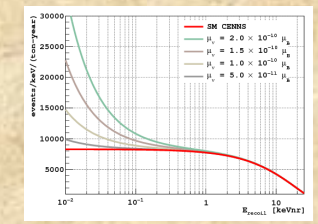
$$G_V = ((g_v^p + 2\epsilon_{ee}^{uV} + \epsilon_{ee}^{dV})Z + (g_v^n + \epsilon_{ee}^{uV} + 2\epsilon_{ee}^{dV})N)F_{nucl}^V(Q^2)$$

$$G_A = ((g_a^p + 2\epsilon_{ee}^{uA} + \epsilon_{ee}^{dA})(Z_+ - Z_-) + (g_a^n + \epsilon_{ee}^{uA} + 2\epsilon_{ee}^{dA})(N_+ - N_-))F_{nucl}^A(Q^2)$$



Search for Neutrino Magnetic Moment

Brice, S.J. *et al.* Phys.Rev. D89 (2014)



There is a big interest from the theory community.

Please see "*Coherent Theory Workshop, Raleigh, NC, January 2015, 30 attendees*"

(http://coherent-theory.phy.duke.edu/)

If we detect it and do not see agreement with the SM – waterfall of ideas will follow

What is the right place to look for Neutrino coherent scattering?

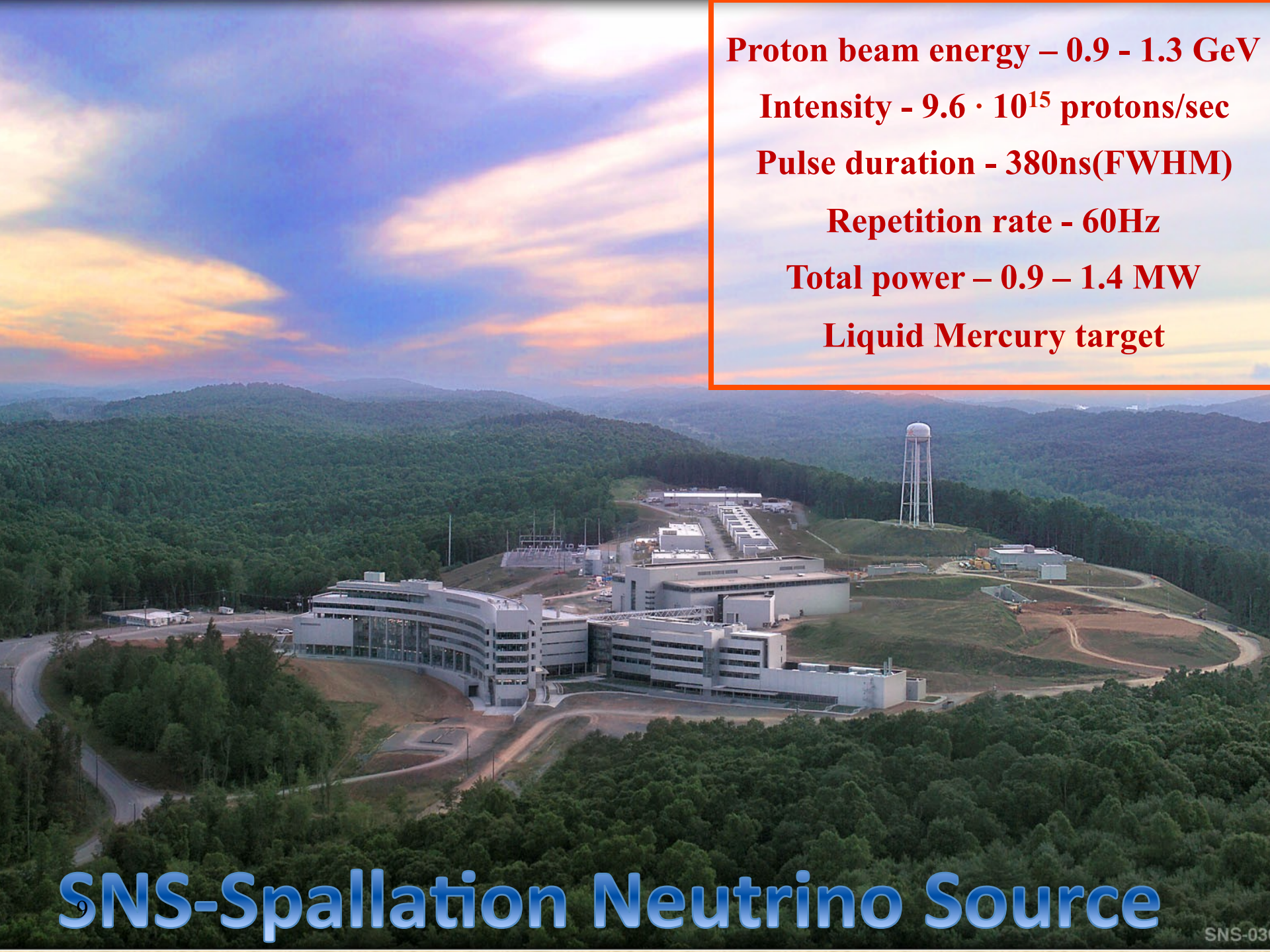
Nuclear reactor or DAR facility

- Huge neutrino flux

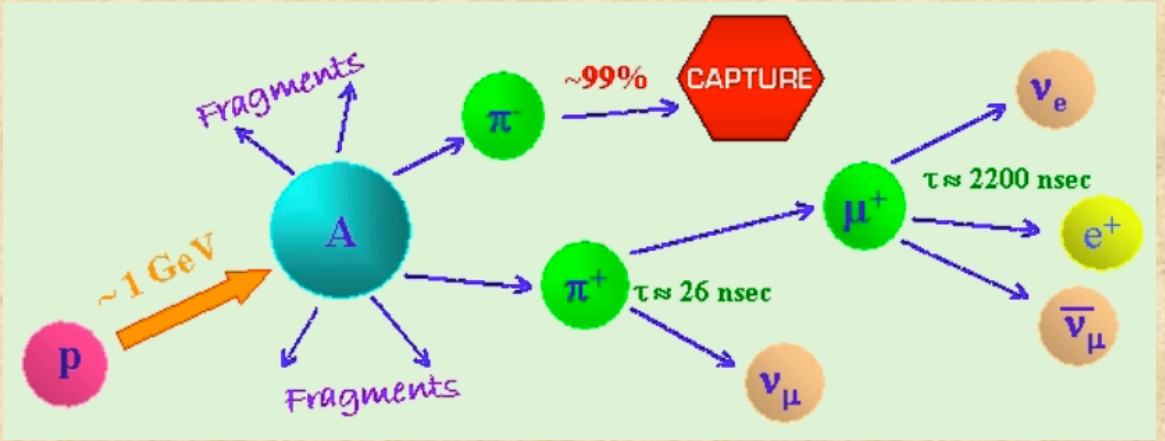
- Just right energy range
- Pulsed structure
- Characteristic time distribution
- Multiple flavors
- Wide mass range of targets

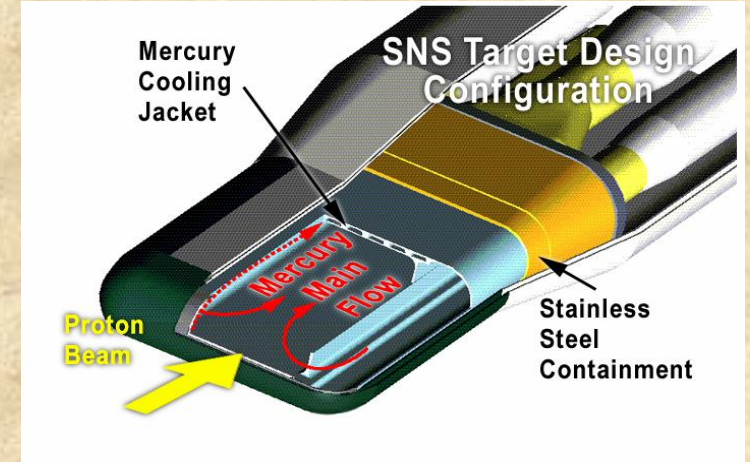
- Low energy: difficult to use heavy targets
- No pulsed structure

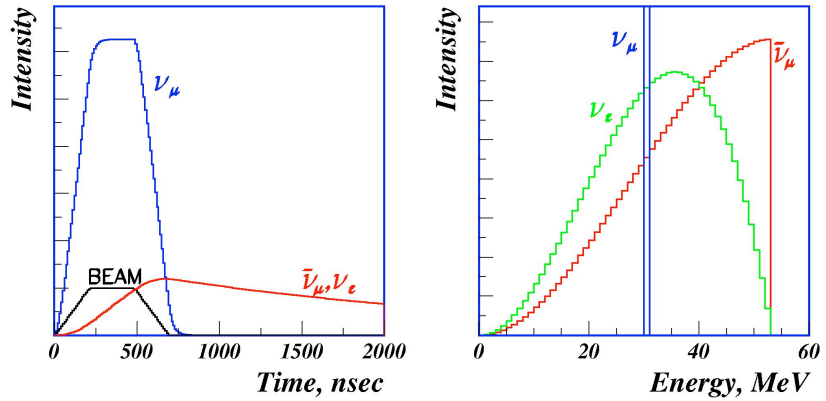
- Not as large flux as at reactor


Proton beam energy – 0.9 - 1.3 GeV
Intensity - 9.6 · 10^15 protons/sec
Pulse duration - 380ns(FWHM)
Repetition rate - 60Hz
Total power – 0.9 – 1.4 MW
Liquid Mercury target
SNS-Spallation Neutrino Source

Neutrino Production at SNS







At present power SNS generates:
~5•10^{20} protons per day,
or ~1•10^{20} neutrinos of 3 flavors per day.

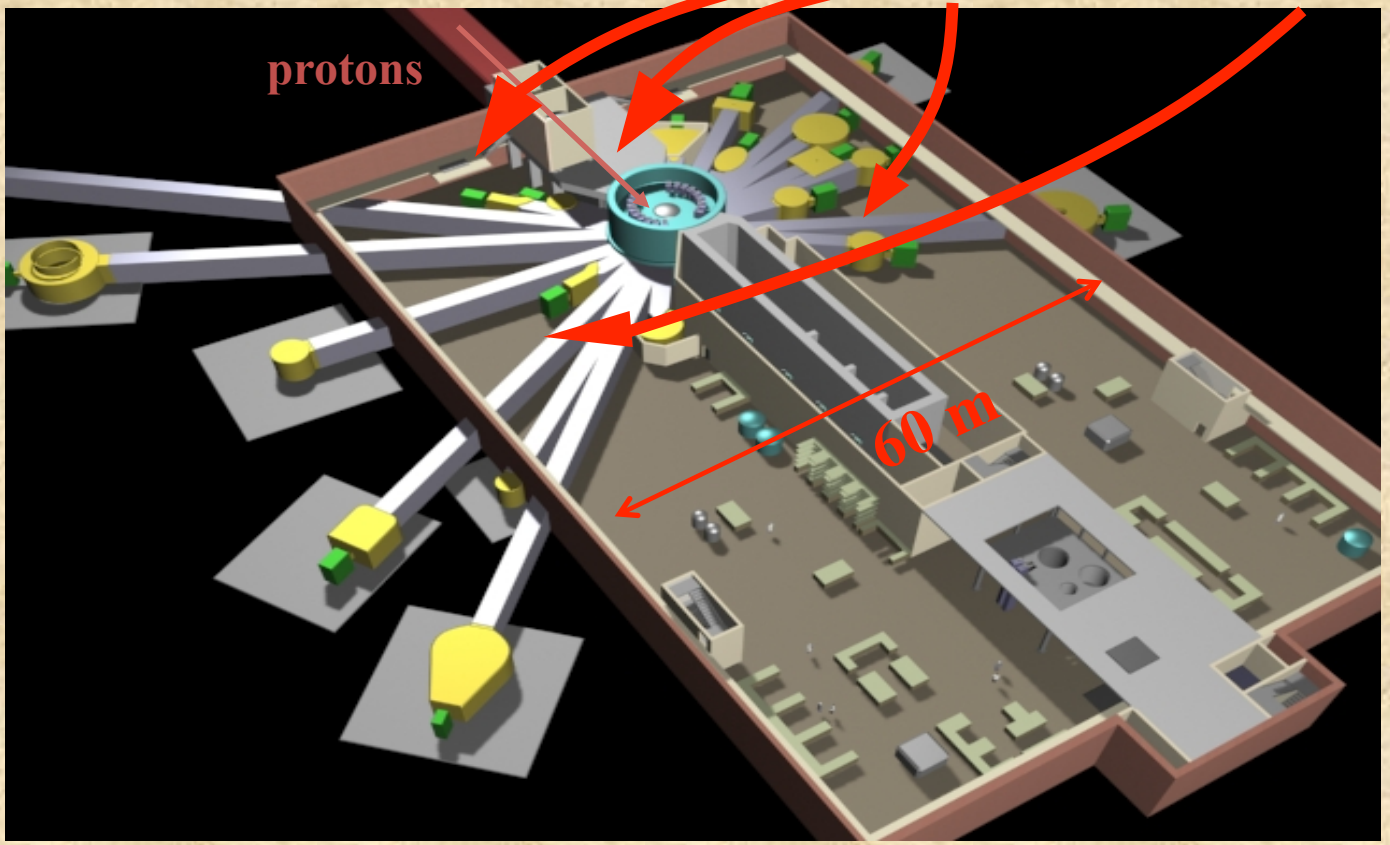
No upgrade or changes in the target are required

Collaboration to make the first detection of the Neutrino Neutral Current Coherent scattering at the SNS

University of California, Berkeley
University of Chicago
Duke University
University of Florida
Indiana University
Institute for Theoretical and Experimental Physics, Moscow
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
National Research Nuclear University MEPhI
North Carolina Central University
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratory
University of Tennessee, Knoxville
Triangle Universities Nuclear Laboratory

Potential Locations for Neutrino Experiment at the SNS

sites inside target building including basement



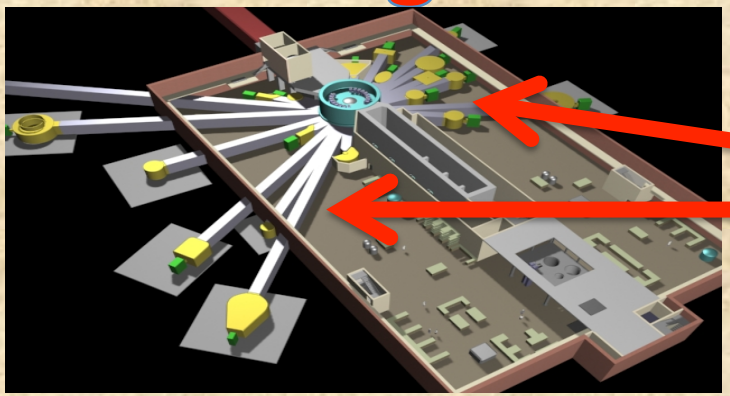
Multiple sites are available at a distance 15-20 m.

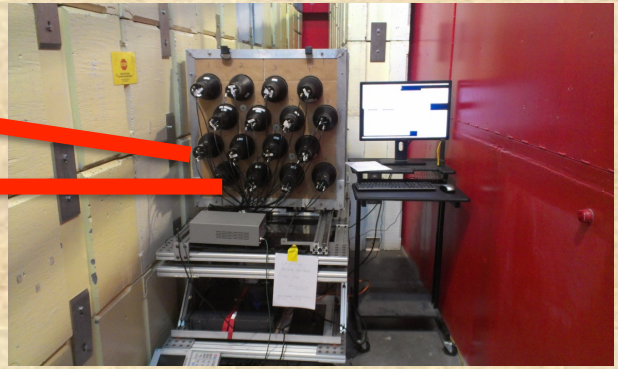
"Green field" is outside of the target building for distances more than 30 m

ORNL is strongly supporting BG studies for neutrino experiment at the SNS

ORNL support: 3 LDRD's (>$300k) + Wigner Fellow

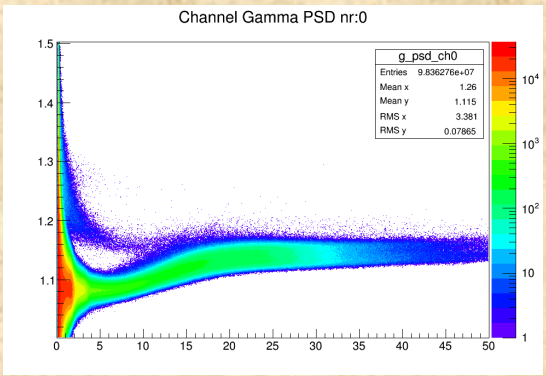
Background Measurements at SNS



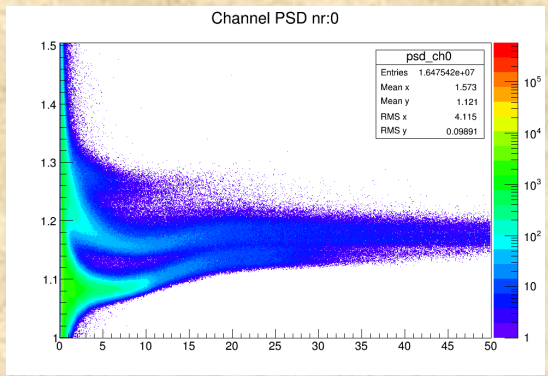


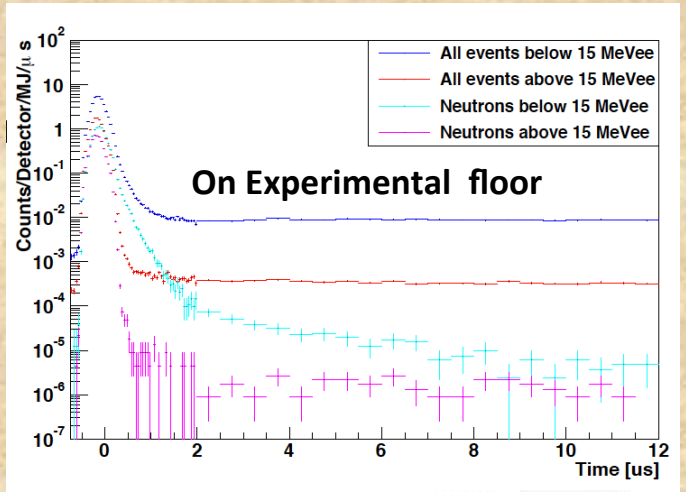
Started in Sept 2013
Tons of data at various locations

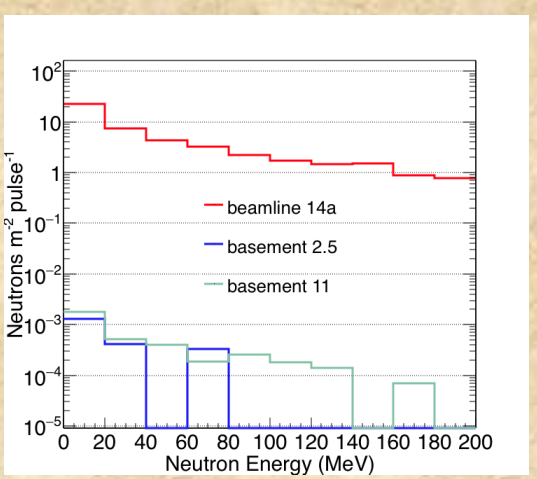
"Out-of-beam" events, primarily muons.



"In-Beam" events, considerably more neutron events

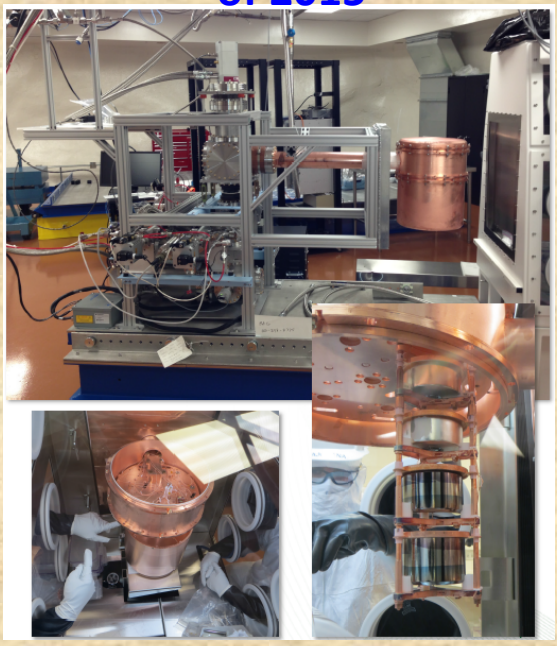






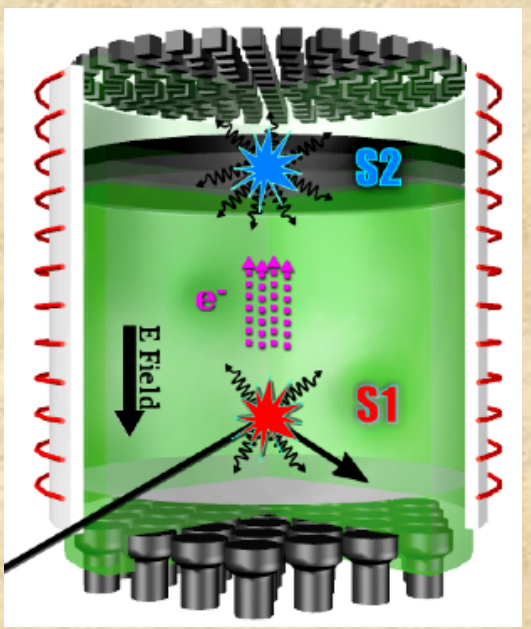
Three detector technologies are "Ready"

MJD prototype cryostat with 20 kg of HPGe detectors, could be available by the end of 2015



14 kg low background CsI crystal is available at the University of Chicago

100 kg, 2 phase LXe is detector being built at MEPhI, Moscow

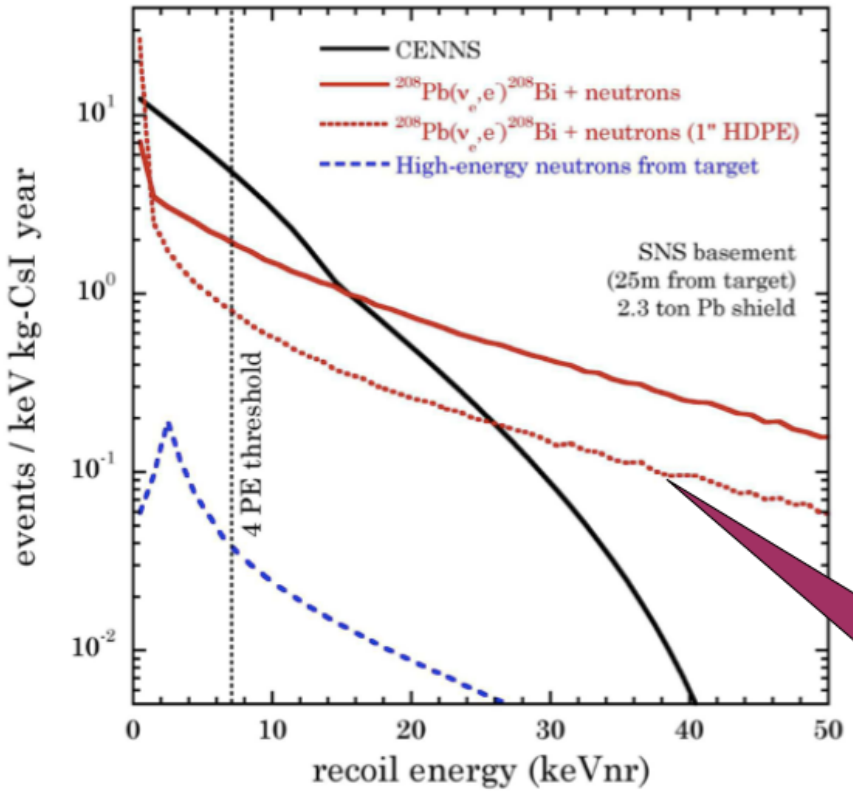


15 m from the target, 100 kg detector, prompt 30 MeV neutrinos

Target	Max Recoil (keV)	Cross section $10^{-42}cm^2$	Threshold, keV_{nr}	N events, year
Ge	27	5830	3	2560
I	15	19400	10	732
Xe	15	22300	1	5970

Realization that neutrinos can induce neutron background in the shielding

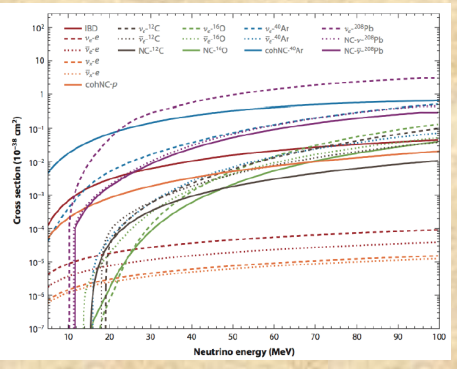
Estimate for a specific configuration (CsI[Na] in lead shield):



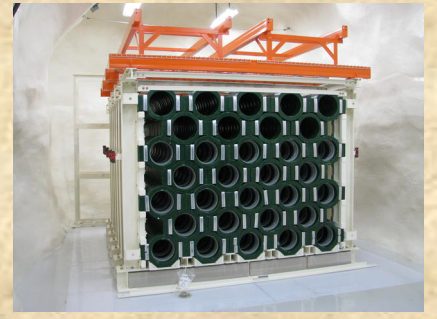
NINs not neglible w/lead shield! ➔ need careful shielding design

arXiv:1407.7524

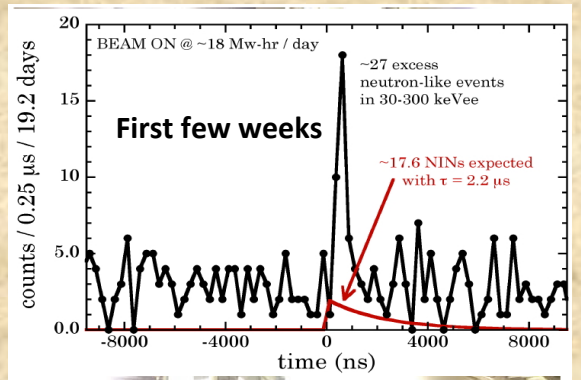
Neutrino Induced Neutrons (NIN)



Never been measured.
There are only theoretical calculations



This reaction on Lead is used by HALO experiment in the SNOlab, to watch for supernovae.



Measurement of NIN → the first neutrino experiment at the SNS

Liquid Scintillator detectors inside Lead, Poly, Cd, Water shield with muon veto

Started in the fall of 2014. By the summer of 2015 should have reasonable statistics to see effect

Planning to measure as well NIN on Iron and Copper for input for Nuclear Theory and shielding optimizations

Conclusion

Neutrino Neutral Current coherent scattering can be measured

This program is pioneered in the U.S.

There is broad interest from test of the SM, to astrophysics, and DM searches

SNS DAR is very attractive place to do experiment

COHERENT collaboration has been created

Good support from ORNL

Detectors for the 'first light" are available (+ international contribution)

Only modest investment required

Fast turn around and possibility to have first physics results within a year

Another possible location for this program is at FNAL (see Rex Tayloe talk)